# Republic of South Africa

## ☞ EDICT OF GOVERNMENT ☜



SANS 6211-1 (2003) (English): Domestic solar water heaters Part 1: Thermal performance using an outdoor test method

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Edition 1

# SWAZILAND NATIONAL STANDARD

## Domestic solar water

## Part 1: Thermal performance using an Outdoor test method

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### Table of changes

| Clause Changed | Date | Change |
| --- | --- | --- |
| | | |

## NATIONAL FOREWORD

This Swaziland National Public Review Draft Standard was prepared by Technical committee *SWASA/TC 33 Solar and Electrical* in accordance with procedures of the Swaziland Standards Authority, in compliance with Annex 3 of the WTO/TBT Agreement. This national public review draft standard is the identical implementation of SANS 6211-1:2003 and is adopted with the permission of the South African Bureau of Standards (SABS).

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**SANS 6211-1:2003**
Edition 1

# SOUTH AFRICAN NATIONAL STANDARD

# Domestic solar water heaters

# Part 1: Thermal performance using an outdoor test method

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**Table of changes**

| Change No. | Date | Scope |
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## Foreword

This South African standard was approved by National Committee STANSA TC 5120.57, *Solar heating systems,* in accordance with procedures of Standards South Africa, in compliance with annex 3 of the WTO/TBT agreement.

This edition cancels and replaces SABS SM 1211:1992.

## Contents

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# Domestic solar water heaters

## Part 1:
Thermal performance using an outdoor test method

## 1 Scope

This part of SANS 6211 describes an outdoor test method for the determination of the thermal performance of domestic solar water heaters.

NOTE The purpose of this test is to determine the long term energy output of a domestic solar water heating system.

## 2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of SANS 6211. All standards are subject to revision and, since any reference to a standard is deemed to be a reference to the latest edition of that standard, parties to agreements based on this part of SANS 6211 are encouraged to take steps to ensure the use of the most recent editions of the standards indicated below. Information on currently valid national and international standards can be obtained from Standards South Africa.

SANS 151 (SABS 151), *Fixed electric storage water heaters.*

SANS 1307 (SABS 1307), *Domestic solar water heaters.*

## 3 Definitions

For the purpose of this standard, the definitions given in SANS 1307 and the following definitions apply:

**3.1**
**agreed**
as agreed upon in writing between the manufacturer and the purchaser

**3.2**
**pyranometer (solarimeter)**
solar radiation measuring instrument. Pyranometers have a hemispherical field of view and are therefore able to measure total irradiance, i.e. the sum of direct, diffuse and ground-reflected solar radiance

# 4 Overall description of outdoor thermal performance test method

## 4.1 Specific test procedure

The test procedure would involve one of the following specific test procedures, as agreed on:

a) **basic thermal performance test**, a series of at least three independent one day outdoor tests to determine the basic thermal performance of a solar water heating system and that is subjected to a single hot water draw-off in the evening (see 4.3 and 5.3.1); or

b) **advanced thermal performance test**, a series of at least six independent one day outdoor tests to determine advanced thermal performance for determining the long-term energy output of domestic solar water heating systems based on a single hot water draw off in the evening (see 4.4).

## 4.2 General test procedure

The tests given in 4.1 above shall be supported by the following tests:

a) a short term test to determine the degree of mixing in the tank during draw-off (see 5.6); and

b) an overnight heat loss test (see 5.7).

The test method given in (a) provides the system characteristic in the form of two parameters, namely, the total energy and the useful energy ratings and is presented by formulae (1) and (2) below:

$$Q_t = C_s \sum_{i=1}^{n} M_m (T_m - T_c) \times 10^{-3} \qquad (1)$$

where

$Q_t$ is the total energy absorbed, in megajoules;

$C_s$ is the heat capacity of the hot water storage tank, in joules per Kelvin;

$n$ is the total number of incremental masses of water added to the measuring tank;

$M_m$ is the incremental mass of water added to the measuring tank (approximately 5 kg), in kilograms;

$T_m$ is the average temperature of each incremental mass of water added to the measuring tank, in the hot water storage tank, in degrees Celsius;

$T_c$ is the incoming cold water temperature, in degrees Celsius.

$$Q_u = C_s \sum_{i=1}^{n} M_m (T_m - T_{20}) \times 10^{-3} \qquad (2)$$

where

$Q_u$ is the useful energy absorbed, in megajoules;

$C_s$ is the heat capacity of the hot water storage tank, in joules per Kelvin;

$n$ is the total number of incremental masses of water added to the measuring tank;

$M_m$ is the incremental mass of water added to the measuring tank (approximately 5 kg), in kilograms;

$T_m$ is the average temperature of each incremental mass of water added to the measuring tank, in the hot water storage tank, in degrees Celsius;

$T_{20}$ is the incoming cold water temperature, in degrees Celsius plus 20 °C.

The test method given in (b) provides the system characteristic in the form of an equation (3) which correlates the energy output of the system $Q$, to the solar energy $H$ incident on the system and the difference between daily average ambient temperature $T_a$ and the incoming cold water temperature $T_c$.

$$Q = \propto_1 H + \propto_2 (T_a - T_c) + \propto_3 \qquad (3)$$

where

$Q$ is the heat output, in megajoules;

$\propto_1$ is the coefficient in equation for heat output of system, in square metres;

$H$ is the irradiation received by a surface over a specified time interval, in megajoules per square metre;

$\propto_2$ is the coefficient in equation for heat output of system, in joules per Kelvin;

$T_a$ is the daily average ambient temperature, in degrees Celsius;

$T_c$ is the incoming cold water temperature, in degrees Celsius;

$\propto_3$ is the coefficient in equation for heat output of system, in joules.

## 4.3 Detailed description of the basic thermal performance tests — One-day heating tests

Each test involves a solar heating period of not less than 6 h, equally spaced about solar noon (i.e. not less than 3 h before and 3 h after solar noon). At least 3 tests with acceptable results are carried out consecutively in accordance with the test method given in 5.3.1.

At the end of each day (after a minimum of 6 h of insulation), the collector is shaded and the accumulated hot water is drawn off at a rate of 600 L/h until 3 times the volume of the storage tank has been discharged, or until the temperature of the draw-off water becomes constant (i.e.

3 consecutive equal temperature readings of the draw-off water with the temperature difference between the draw-off water and the water entering the storage tank being less than 1 K), whichever occurs first. During the draw-off, temperatures are to be taken at volume withdrawal increments of $V_s$ / 20. The values of temperature versus volume withdrawn are plotted on a draw-off profile graph (see figure 1) and the energy output for each test day is determined by measuring the area under the curve and above $T_c$.

$V_s$ / 20

where

$V_s$ is the volume of hot water in the storage tank, in litres.

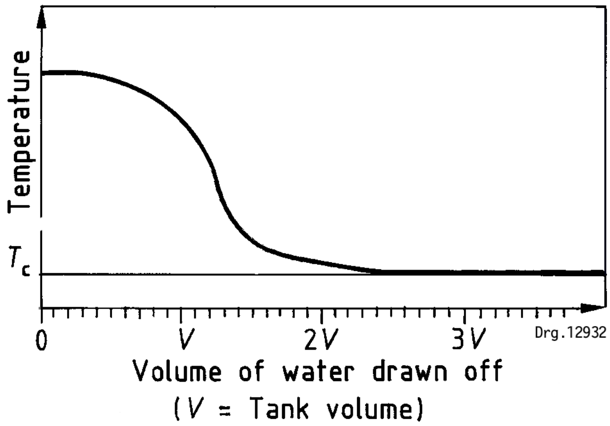


**Figure 1 — Typical example of energy output and mixing draw-off profile**

## 4.4 Detailed description of the advanced thermal performance tests — One-day heating tests

Each test involves a solar heating period of not less than 6 h, equally spaced about solar noon (i.e. not less than 3 h before and 3 h after solar noon). At least 6 tests with acceptable results are carried out consecutively in accordance with the test method given in 5.3.2. Three of the test results from 5.3.1 may be used. Table 1 gives an example of the typical test sequence though the precise sequence of tests need not be followed. The irradiation $H$ and the values of ($T_a$ – $T_c$) are caused to be different for each test in order to allow the dependence on the parameters to be established. $T_c$ is closely controlled for each day.

($T_a$ – $T_c$)

where

$T_a$ is the daily average ambient temperature, in degree Celsius;

$T_c$ is the incoming cold water temperature.

**Table 1 — Example summary of one-day tests for advanced thermal performance assessment**

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| **Test day No.** | **Approximate irradiation ($H$)** (MJ/m$^2$) | **Temperature difference** (K) | **Drawn-off volume** | **Drawn-off time** |
| 1 | 10 | $(T_a - T_c)_1$ | $3V_s$ | solar noon + 5h |
| 2 | 15 | $(T_a - T_c)_1$ | $3V_s$ | solar noon + 5h |
| 3 | 20 | $(T_a - T_c)_1$ | $3V_s$ | solar noon + 5h |
| 4 | 25 | $(T_a - T_c)_1$ | $3V_s$ | solar noon + 5h |
| 5 | 10 | $(T_a - T_c)_2$ | $3V_s$ | solar noon + 5h |
| 6 | 20 | $(T_a - T_c)_2$ | $3V_s$ | solar noon + 5h |

NOTE 1 $(T_a - T_c)_2 = (T_a - T_c)_1$ +10 K.
NOTE 2 $(T_a - T_c)_1$ and $(T_a - T_c)_2$ are between -5 K and +20 K.
NOTE 3 $T_a$ is the daily average ambient temperatures.
NOTE 4 $T_c$ is the incoming cold water temperature.
NOTE 5 $V_s$ is the volume of the hot water storage tank.

At the end of each day (after at least 6 h of isolation), the collector is shaded and the accumulated hot water is drawn-off at a rate of 600 L/h until 3 times the volume of the storage tank has been discharged, or until the temperature of the draw-off water becomes constant (i.e. 3 consecutive equal temperature readings of the draw-off water with the temperature difference between the draw-off water and the water entering the storage tank being less than 1 K), whichever occurs first. During the draw-off, temperatures are to be taken at volume withdrawal increments of $V_s$ / 20. The values of temperature versus volume withdrawn are plotted on a draw-off profile graph (see figure 1) and the energy output for each test day is determined by measuring the area under the curve and above $T_c$.

## 5 Test for thermal performance (without operation of auxiliary heaters)

### 5.1 Apparatus (for basic and advanced methods)

**5.1.1 Test loop**, erected as shown in figure 2.

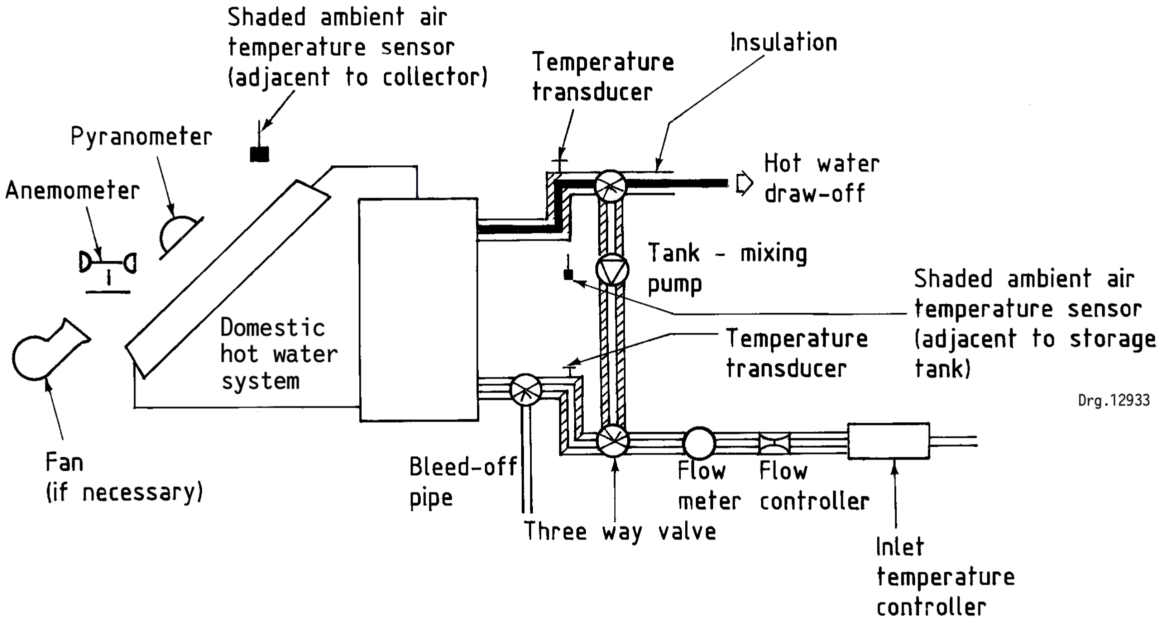


**Figure 2 — Schematic presentation of loop for thermal performance tests**

**5.1.2 Fan**, of suitable capacity, and furnished with an air spreader on the delivery side, to ensure a wind speed of between 3 m/s and 8 m/s, evenly directed over the full face of the collector and parallel to the face.

**5.1.3 Water supply**, of 600 L/h, with the inlet temperature of the cold water supply ($T_c$) adjusted so that the difference between the daily average ambient temperature ($T_a$) and the cold water supply temperature ($T_c$), ($T_a - T_c$), varies between -5 K and +20 K (i.e. 4 °C ≤ $T_c$ ≤ 33 °C) but is capable of being maintained at the specific predetermined value subject to a tolerance of 0,5 K.

**5.1.4 Hot water storage tank, collector and interconnecting pipes**, comprising either

a) a complete system as presented by the manufacturer and when relevant, erected in accordance with the manufacturer's written instructions (insulation for the interconnecting pipework shall be supplied by the manufacturer, complete with the application procedure), or

b) collector(s) only and, as supplied by the manufacturer, a hot water storage tank complying with SANS 151 and interconnecting pipework of length, size, insulation and installation as agreed.

**5.1.5 Pyranometers**, as classified by the World Meteorological Organization (WMO), in accordance with table 2.

**Table 2 — Classification of pyranometers**

| 1 | 2 | 3 | 4 |
|---|---|---|---|
| **Characteristic** | **Secondary standard** | **First class** | **Second class** |
| Resolution (smallest detectable change in W/m$^2$ ) | ± 1 | ± 5 | ± 10 |
| Stability (percentage of full scale recording, change/year) | ± 1 | ± 2 | ± 5 |
| Cosine response (percentage deviation from ideal at 10° solar elevation on a clear day) | < ± 3 | < ± 7 | < ± 15 |
| Azimuth response (percentage deviation from the mean at 10° solar elevation on a clear day) | < ± 3 | < ± 5 | < ± 10 |
| Temperature response (percentage maximum error due to change of ambient temperature within the operating range) | ± 1 | ± 2 | ± 5 |
| Non-linearity (percentage of full scale recording) | ± 0,5 | ± 2 | ± 5 |
| Spectral sensitivity (percentage deviation from mean absorptance 0,3 μm to 3 μm) | ± 2 | ± 5 | ± 10 |
| Response time (99 % response) | < 25 s | < 1 min | < 4 min |
| NOTE Only pyranometers meeting the WMO secondary standard or 1st class classifications should be used for collector and system testing. Those most commonly used in Europe are the models CM10 and CM11 manufactured by Kipp and Zonen in the Netherlands and the model PSP manufactured by Eppley in the USA. The CM10, CM11 and PSP are all secondary standard instruments. The accuracy of photovoltaic pyranometers has not yet been shown to meet the requirements of collector and system testing. | | | |

**5.1.6 Water flow controller**, that is capable of controlling the water flow rate through the system during the draw-off periods to 600 L/h ± 10 L/h.

**5.1.7 Temperature transducers,** of the following types:

a) **water temperature transducers,** of the appropriate number and with an accuracy of ± 0,1 K and a precision of ± 0,1 K; and

b) **ambient flow controller,** with an accuracy of ± 0,5 K and a precision of ± 0,2 K, placed in a shaded, aspirated enclosure 1 m above ground, between 1,5 m to 10 m from the system under test.

**5.1.8 Draw-off water measuring instrument**, that consists of either

a) a 600 L/h flow-rate meter with an accuracy of ± 3 %, or

b) a collection tank of capacity at least 1 000 L, complete with a mass transducer of accuracy ± 3,0 % and of capacity at least 1 000 kg.

**5.1.9 Wind speed meter**, capable of measuring wind speed in the range 0 m/s to 10 m/s to an accuracy of ± 5,0 %.

**5.1.10 Instrumentation data recorders**, of the appropriate number and types and having the following features:

a) **data recorders (analog and digital recorders)**, of accuracy at least equal to ± 0,5 % of the full scale recording a time constant not exceeding 1 s and a peak signal indicating of between 50 % and 100 % of the full scale;

b) **integrators (digital and electronic integrators)**, of accuracy at least equal to 1,0 % of the measured value;

c) **input impedance recorders**, shall be the greater of 1 000 times the impedance of the sensors and 10 mΩ; and

d) **instrument small scale division:** the smallest scale division of the instrument or instrument system shall not exceed twice the specified precision, e.g. if the specified precision is ± 0,1 K, the smallest scale division shall not exceed 0,2 K.

## 5.2 System mounting and location

### 5.2.1 Pyranometers

**5.2.1.1** The pyranometer shall be so mounted that its detector is located in the plane of, and in close proximity to, the collector.

NOTE Pyranometers are primarily designed for use in a horizontal position and are fitted with a large white disc to shade the instrument body from solar radiation.

**5.2.1.2** When pyranometers are used in a tilted position, additional protection is required to shade the back of the instrument from diffuse solar radiation.

NOTE Pyranometers should be well ventilated with ambient air on all surfaces both in front and behind the solar panel, since any heating of the instrument body is likely to cause measurement errors.

**5.2.1.3** The cables shall be shielded from direct solar radiation and screened from electromagnetic interference.

**5.2.1.4** Prior to collector or system testing, the glass dome of the pyranometer shall be cleaned and checked to ensure that it is free of condensation.

**5.2.1.5** If condensation is present, the desiccant in the instrument shall be dried. No condensation shall be accepted whilst the instrument is in use.

**5.2.1.6** Pyranometers shall be calibrated in accordance with the recommendations of the WMO to the World Radiometric Reference and recalibrated annually either by the manufacturer, or by an accredited meteological laboratory.

**5.2.1.7** The variation of most pyranometer calibrations with tilt angle is small (< 1 %), but if possible the pyranometer should be calibrated at the tilt angle at which it will be used.

NOTE The zero offset of a pyranometer may be checked by placing a light-tight box over it, a pyranometer will not always give a zero reading outdoors at night because of the low values of effective sky temperature which sometimes occur. Low sky temperatures depress the zero reading of pyranometers.

### 5.2.2 System mounting

Mount the system in accordance with the manufacturer's installation instructions or otherwise in a manner as agreed upon.

### 5.2.3 Tilt angle and orientation of collector(s)

**5.2.3.1 For outdoor, natural solar irradiance**, the collector(s) shall be installed facing due north and at a tilt angle,

a) as specified by the manufacturer in his installation instruction, or

b) if installation instructions are not given, at latitude plus 10°.

**5.2.3.2 For indoor (artificial) solar irradiance,** the collector shall be installed as agreed upon, and as described in the testing authority's brochure.

### 5.2.4 Ensuring direct irradiance

So position the collector(s) that no shadow will be cast on them at any time during the test period.

### 5.2.5 Diffused and reflected irradiance

Ensure as far as possible, that diffused and reflected solar irradiance is prevented from reaching the collector. (Particular care shall be taken to avoid reflections from large surfaces of glass, metal, water or painted walls.)

### 5.2.6 Thermal irradiance

Ensure that the temperature of surface adjacent to, or in close proximity to, the test apparatus is as close as possible to ambient temperature.

## 5.3 Procedure

### 5.3.1 Procedure for the three one-day heating tests (basic thermal performance)

**5.3.1.1** Fully cover the collector and ensure that the system temperature has stabilized by flushing the complete system until the temperature of the delivery water becomes constant and within 1 K of the supply water temperature ($T_c$).

**5.3.1.2** Uncover the collector and immediately switch on the solarimeter and anemometer recorders, also record the ambient temperature at approximately 30 min intervals. Allow the solar collector to heat up for a period of not less than 3 h before solar noon and 3 h after solar noon.

**5.3.1.3** At the end of the test period (6 h minimum) cover the collectors and immediately switch off the solarimeter, the anemometer and ambient temperature recorders. Open the outlet valve from the storage container. Open the cold water supply and eject all the hot water from the system at a flow rate of 600 L/h ± 10 L/h, while recording the temperature of the draw-off water and measuring the volume of water delivered at increments of approximately $V_s$ / 20.

**5.3.1.4** Draw the accumulated hot water off until a stage is reached when three successive temperature measurements do not vary by more than 1 K above $T_c$, or until three times the volume of the storage tank has been discharged, whichever occurs first.

**5.3.1.5** Close the hot water draw-off valve.

**5.3.1.6** Plot the values obtained for the volume versus temperature graph, and calculate $Q_t$ which is the integrated area under the curve up to $T_c$.

**5.3.1.7** Calculate the useful energy rating ($Q_u$) which is the area under the volume versus temperature graph but up to $T_{20}$, which is 20 °C higher than $T_c$.

### 5.3.2 Procedure for the one-day heating test (advanced thermal performance)

#### 5.3.2.1 First day test

**5.3.2.1.1** Fully cover the collector and select and adjust the temperature of the cold water supply such that ($T_a$ – $T_c$) is at a value of between -5 K and + 20 K. Record the temperature of the cold water supply and maintain this temperature to within ± 0,5 K for the rest of this one-day test.

**5.3.2.1.2** Flush the complete system until the temperature of the delivery water becomes constant at not more than 1 °C above or below $T_c$. Close the flushing valve.

**5.3.2.1.3** Measure the wind speed over the collector surface and, if necessary, adjust the wind speed (by means of the blower) to a speed of between 3 m/s and 8 m/s.

**5.3.2.1.4** Start the test not more than 3 h before solar noon, by removing the collector shield. Immediately switch on the solarimeter and the anemometer and record the ambient temperature at intervals of not more than 30 min. Allow the system to operate under the influence of the sun for at least the next 6 h.

**5.3.2.1.5** Control the total daily radiation (by using a suitable shading device) to about 10 MJ/m$^2$.

**5.3.2.1.6** At the end of the test (after 6 h minimum), fully shade the collector again and immediately switch off the meters recording the wind speed, ambient temperatures and the solar irradiation.

**5.3.2.1.7** While ensuring that the inlet water temperature ($T_c$) does not fluctuate by more than 0,5 K and does not drift by more than 1,0 K during the draw-off, open the hot water draw-off valve and draw-off water from the system at a flow rate of 600 L/h ± 10 L/h, while recording the temperature of the draw-off water and measuring the precise volume of water delivered at increments of approximately $V_s$ / 20.

**5.3.2.1.8** Draw the accumulated hot water off until a stage is reached when three successive temperature measurements do not vary by more than 1 K above $T_c$, or until three times the volume of the storage tank has been discharged, whichever occurs first.

**5.3.2.1.9** Close the hot water draw-off valve.

**5.3.2.1.10** Calculate the energy output of the system $Q$ and plot the curves obtained on graphs as shown in figures 3 and 4.

#### 5.3.2.2 Second, third and fourth day tests

Repeat the procedure given for the first day test with total daily irradiation values of 15 MJ/m$^2$, 20 MJ/m$^2$, 25 MJ/m$^2$ respectively, while maintaining the value of ($T_a$ – $T_c$) approximately the same as for the first day's test.

#### 5.3.2.3 Fifth day test

Repeat the procedure given in 5.3.2.2, ensuring that ($T_a$ – $T_c$) is 10 K ± 2 K higher than the value of ($T_a$ – $T_c$) for days one to four and that the value of the daily irradiation is approximately 10 MJ/m$^2$.

#### 5.3.2.4 Sixth day test

Repeat the procedures in 5.3.2.3, ensuring that the total daily radiation is approximately 20 MJ/m$^2$.

## 5.4 Calculations

**5.4.1** From the results of the 6 one-day tests (5.3.2.1 to 5.3.2.4), determine the values of the coefficients $\propto_1$, $\propto_2$ and $\propto_3$.

**5.4.2** Calculate the energy output of the system by using the following formula:

$$Q = \propto_1 H + \propto_2 (T_a - T_c) + \propto_3 \qquad (4)$$

where

| | |
|---|---|
| $Q$ | is the energy output in megajoules; |
| $H$ | is the energy input (irradiation), in megajoules per square meter; |
| $(T_a - T_c)$ | is the difference in ambient air temperature and cold water supply temperatures, in kelvin; |
| $\propto_1$, $\propto_2$ and $\propto_3$ | are the specific coefficients as determined in 5.4.1. |

## 5.5 Energy input and output

The energy input (solar irradiation $H$) and the corresponding energy output (energy in the water draw-off) for each test day and in respect of a particular value of $(T_a - T_c)$ are plotted on an energy input/output graph (see figure 3).

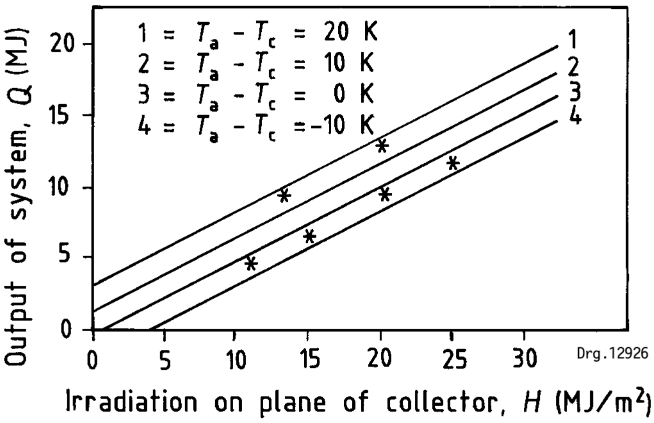


**Figure 3 — Typical example of energy input/output graph**

The values of the energy output and the temperature $(T_a - T_c)_1$ and $(T_a - T_c)_2$, which respectively, correspond to a daily total of solar insulation of $H$ = 10 MJ/m$^2$ and $H$ = 20 MJ/m$^2$ (see table 1) are plotted on the energy output/temperature graph (figure 4).

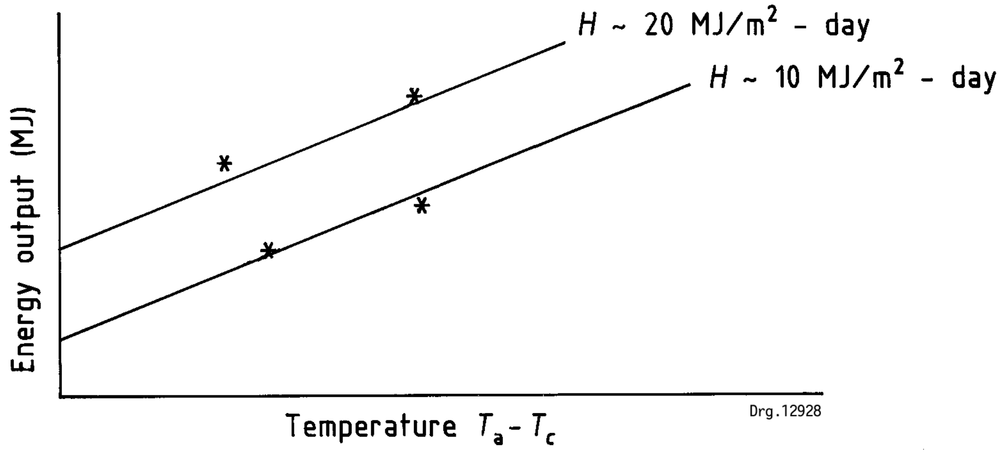


**Figure 4 — Typical example of energy output/temperature graph**

## 5.6 Determining the degree of mixing in the hot water storage tank during draw-off

### 5.6.1 General

The purpose of the test is to develop a mixing draw-off profile by drawing off water from the hot water storage tank, which has been pre-heated to a uniform high initial temperature $T_i$ (where $T_i > 60$ °C).

### 5.6.2 Procedure

**5.6.2.1** Bring the water to a uniform temperature by circulation using a by-pass pump.

**5.6.2.2** Draw-off a volume equivalent to at least three times the storage volume of the hot water tank ($V_s$) at draw-off rate of 600 L/h ± 10 L/h.

**5.6.2.3** Ensure that the inlet water temperature is less than 30 °C and any auxiliary heaters (except heaters to adjust the incoming water temperature) are switched off.

**5.6.2.4** Monitor the temperature of the water drawn-off in respect of each increment of water equal to $V_s$ / 10, and a mixing profile similar to that in figure 1 is developed.

## 5.7 Determining the overnight heat loss of the hot water storage tank

### 5.7.1 General

The purpose of this test is to determine the heat loss coefficient of the storage tank. The test is performed on the system as installed in accordance with the manufacturer's instructions.

### 5.7.2 Procedure

**5.7.2.1** Bring in the hot water storage tank up to a uniform temperature $T_i$ (where $T_i > 60$ °C) and switch off any auxiliary heaters.

**5.7.2.2** Allow the hot water storage tank to cool for a period of about 12 h between sunset and sunrise, under the influence of a wind speed of 3 m/s to 4 m/s and ambient temperature.

**5.7.2.3** Record the ambient temperature every hour.

**5.7.2.4** The final temperature ($T_i$) of the water in the hot water storage tank is measured after the water has been thoroughly mixed to ensure a uniform temperature.

**5.7.2.5** Calculate the heat coefficient ($U_s$) from the following formula:

$$U_s = \frac{C_s}{t} \ln \left[ \frac{T_i \quad T_{as}}{T_f - T_{as}} \right]$$

where

$U_s$ is the heat loss coefficient, in watts per kelvin;

$C_s$ is the heat capacity of the hot water tank, in joules per kelvin;

$t$ is the test period, in seconds;

$T_i$ is the initial temperature in the hot water storage tank, in degrees Celsius;

$T_{as}$ is the average ambient temperature, in degrees Celsius;

$T_f$ is the final temperature in the hot water storage tank, in degrees Celsius.

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